NATIONAL BUREAU OF STANDARDS REPORT

7706

Development of a Transmissometer Calibrator

By
C. A. Douglas
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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT 0201-20-02411

September 1962

NBS REPORT 7706

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By
C. A. Douglas
J. W. Simeroth
Photometry and Colorimetry Section
Metrology Division

For
Bureau of Naval Weapons
Department of the Navy
Washington 25, D.C.

NBS

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ABSTRACT

This report describes a calibrator developed for use in adjusting the transmissometer. The results of field tests of the instrument and operating instructions are included. With the calibrator, used carefully, the expected error in the setting of the transmissometer is approximately 0.015 when the transmittance over the transmissometer baseline is 0.90 or greater.

1. INTRODUCTION

To facilitate the interpretation of the transmissometer readings, the instrument is adjusted so that if the air were perfectly clear, transmittance 1.00, a reading of 100 would be obtained on the indicator meter. This adjustment is obtained by carefully estimating the visibility, choosing, if possible, a time when the visibility is high; determining the transmissometer reading corresponding to this visibility; and adjusting the iris diaphragm at the receiver to obtain this reading. This method is satisfactory if the following conditions are met.

1. Visibilities of 10 miles or more occur at least once weekly.

2. There are sufficient visibility marks at distances of 8 to 20 miles to permit a reasonably accurate estimate of the visibility.

3. The atmospheric conditions in the vicinity of the transmissometer are representative of the conditions over the area at the time these visibility estimates are made.

There are, however, locations where one or more of the above conditions are not met. Therefore, a method of making the 100 percent setting adjustment which is not dependent upon these conditions is needed.

The calibrator used in determining the 100 percent setting should meet the following requirements:

1. The accuracy with which the transmissometer can be adjusted using the calibrator should be at least as high as that with which the transmissometer can be adjusted by using the extrapolation procedure.

2. The installations required on the field should be simple and inexpensive.

3. The calibration adjustment of the calibrator should be easily accomplished in the field with a minimum of equipment.

4. Determination of the 100 percent setting of the transmissometer by means of the calibrator should be simple and require a minimum of adjustment and computation.

The instrument described below was designed to meet these requirements.

2. THEORY OF OPERATION

2.1 Photometric Theory

The design of the instrument is based upon the fact that the atmospheric transmittance can be obtained from the measurement of the illuminance from a reference projector at two different distances if the transmittance is uniform over the range of distances used. The results are independent of the sensitivity of the receiver and the intensity of the projector if these characteristics are stable.

The transmissometer projector is used as the reference light. A portable photoelectric photometer is used to determine the illuminance at the two distances. The greater of these distances, D, is the transmissometer range. The shorter distance, d, is made one-fifth of this distance. These two positions will be referred to as the FAR and the NEAR positions, respectively. The distance to the NEAR position is sufficiently large that the illuminance from the projector follows the inverse square law. The two points of measurement and the projector are colinear.

Therefore $$E_d = It_d/d^2 \qquad (1)$$

and $$E_D = It_D/D^2 \qquad (2)$$

where E is the illuminance, I the intensity, and t the transmittance over the path indicated.

These equations can be solved simultaneously for t_D, the transmittance of the transmissometer path, using the relation $t_d = t_D^{0.2}$.

Therefore
$$t_D = [(E_D D^2)/(E_d d^2)]^{1.25} \qquad (3)$$

The instrument is made direct reading in the following way:

Let θ_D be the instrument output at the FAR position, distance D, and θ_d the output at the NEAR position, distance d. If the sensitivity of the instrument is changed by means of a range-changing switch to an appropriate value at each of the two positions,

$$\theta_D = k_D E_D$$

$$\theta_d = k_d E_d$$

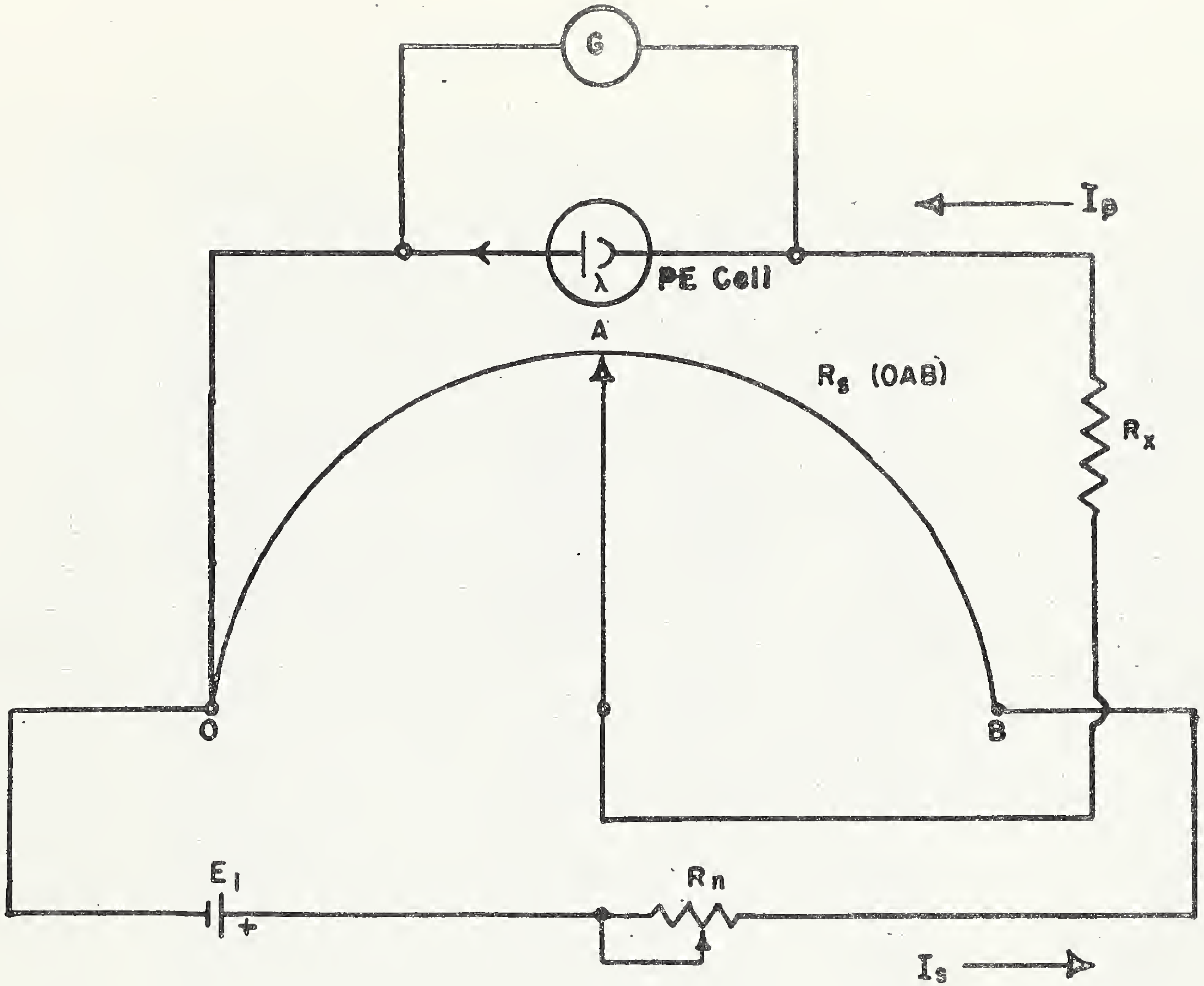
where k_D and k_d are the sensitivity constants of the instrument when it is at the FAR and NEAR positions, respectively. If k_D/k_d is made equal to D^2/d^2 by the design of the instrument, then

$$t_D = (\theta_D/\theta_d)^{1.25} \qquad (4)$$

To further simplify the procedure, the Calibrator is adjusted at the NEAR position so that θ_d is made 1.00 while the ratio k_D/k_d is maintained unchanged, and the scale, instead of being linear with θ_D, is graduated in terms of $(\theta_D)^{1.25}$.

Hence t_D is indicated directly, and the iris diaphragm of the transmissometer receiver is adjusted to give the same reading on the transmissometer indicator as was obtained on the Calibrator. No computations are required.

Note that neither the intensity of the projector nor the sensitivity of the receiver need be known. The only requirements are that these quantities remain constant during a calibration, that the atmospheric transmittance over the transmissometer baseline be uniform and constant throughout the calibration, and that the sensitivity in the FAR position be 25 times that in the NEAR position. Calibration of the Calibrator, therefore, consists only of making this sensitivity ratio precisely 25. As will be shown later (Appendix A, Section A.2) this calibration does not require elaborate auxiliary photometric instrumentation.



Simplified Circuit Diagram

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Figure 1

2.2 Electronic Circuitry

2.2.1 Basic Design. The Calibrator consists of a barrier-layer photocell (Weston Photronic Model 856 Type RR) with a stray light shield, a telescoping stand for supporting the cell, and an indicating unit using a zero-resistance circuit. A simplified circuit diagram is shown in figure 1. From this it is seen that when the photocell current I_p is small in comparison with the slidewire current I_s and the current through the galvanometer is zero,

$$I_p = \theta R_s I_s / R_x$$

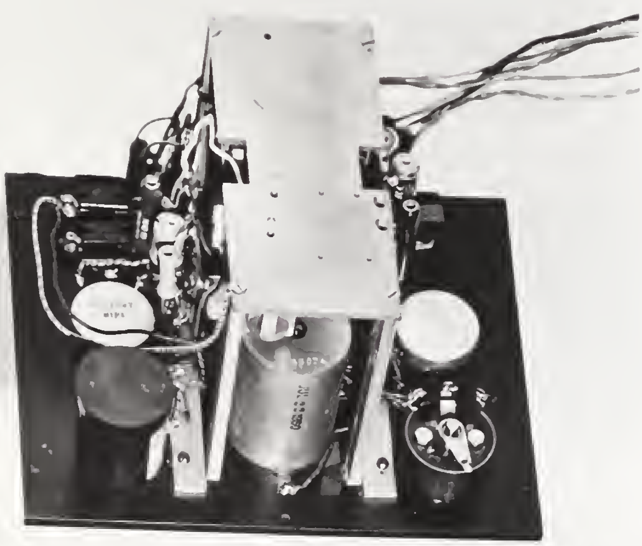
$$\text{or} \qquad \theta = I_p (R_x / R_s I_s) \tag{5}$$

where θ is the output of the instrument (θ_D and θ_d of equation 4) expressed as the ratio of the slidewire resistance between the point of contact A and 0 to the total resistance between B and 0.

θ_d is made equal to 1.00 when the Calibrator is installed at the NEAR position by adjusting I_s by means of R_n. When the Calibrator is moved to the FAR position, R_x is increased by switching so that the output of the instrument θ_D is approximately 25 times as great as it would have been had R_x been left at the value which was used at the NEAR position. If the response of the photocell were completely linear over the range of illuminances encountered, the value of R_x at the FAR position would be exactly 25 times the value at the NEAR position..

Figures 2 and 3 are photographs of the Calibrator.

a. Front View

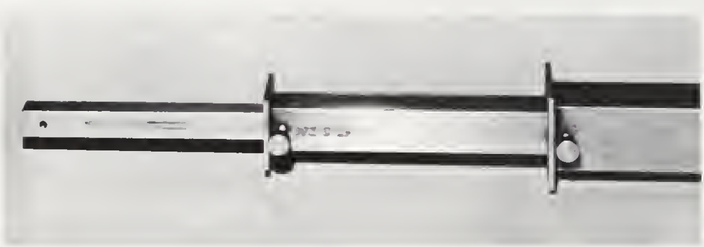


8"

b Rear View

Transmissometer Calibrator Control Box

a. Photocell with shield, shown on FAR position holder.

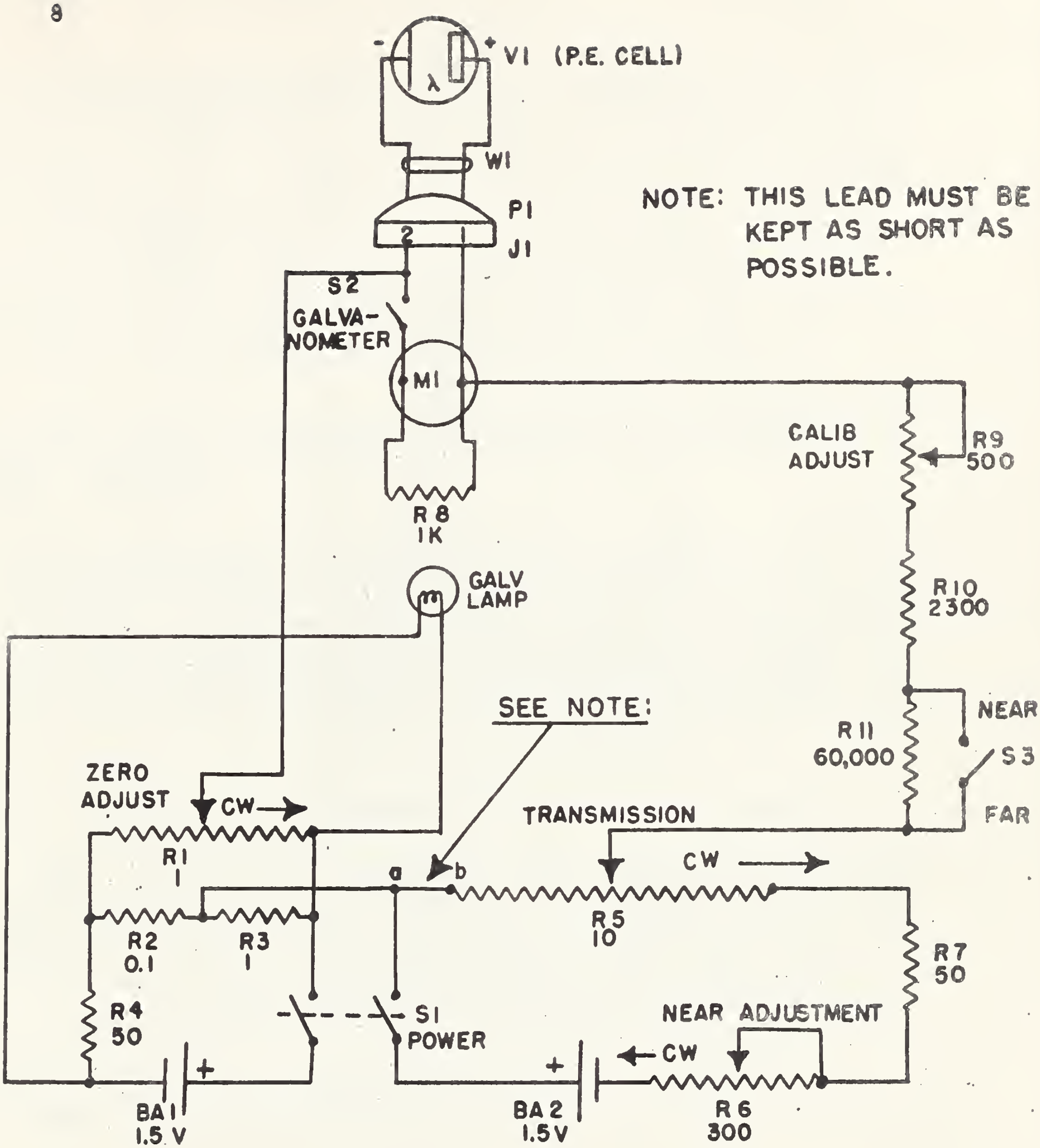


12"

b. Section of the telescoping stand used at the NEAR position.

Transmissometer Calibrator Receiver

Figure 3



Schematic Diagram, Transmissometer Calibrator

2.2.2 Details of Circuit Design. A detailed schematic of the Calibrator is shown in figure 4, and a components list is given in table I. Note that R_5 is the slidewire, R_s, shown in figure 1. The current through the slidewire, I_s, is adjusted by R_6 (R_n of figure 1), thereby changing the position on R_5 at which a null on the galvanometer is obtained for a given photoelectric current, I_p. (See equation 5.) When switch S_3 is closed, R_9 and R_{10} constitute R_x of figure 1 and of equation 5. When this switch is open, the value of R_x is increased to approximately 25 times the former value. Adjustment of the value of R_9 is used to compensate for nonlinearity of the photocell, thus making the ratio of the instrument sensitivities, k_D/k_d, precisely 25.

The network R_1, R_2, R_3, and R_4 provides an electrical adjustment of the galvanometer zero. This adjustment is used as a fine adjustment to supplement the mechanical zero adjustment and to compensate for the background illumination.

To eliminate shifts in the galvanometer zero with changes in the setting of the NEAR ADJUSTMENT, the resistance of the lead between points a and b must be kept as low as possible. Therefore the lead from the junction of R_2 and R_3 is connected to the terminal of R_5. In addition, to keep the resistance between this terminal and the zero position of the slider as low as possible, a copper wire is connected between the terminal and a point on the first turn adjacent to the point of contact of the slider.

Detailed operating instructions are given in Appendix A.

Data for graduating the TRANSMISSION scale are given in Appendix B.

NOTE: The Calibrator described here was designed and constructed several years ago. Solid state components and circuitry have developed rapidly in the ensuing years. Two of these developments should be considered for use in future Calibrators of this type: (a) The use of a silicon barrier-layer cell instead of the present selenium cell, and (b) the use of a battery-powered transistorized null detector instead of the galvanometer. These changes would require no modification of the present circuitry other than changes in the values of resistors R_9, R_{10}, and R_{11}. They would increase the sensitivity and hence the ease of obtaining a balance at the FAR position.

Table I

Components List for the Transmissometer Calibrator

V_1	Weston Model 856 Type RR photronic cell
M_1	Rubicon Cat. #3072 galvanometer
J_1	Amphenol PC2F
P_1	Amphenol MC2M
S_1	DPST Toggle (POWER)
S_2	SPST Toggle (GALVANOMETER)
S_3	SPST Toggle (POSITION)
BA_1	1.5v, Type 4F
BA_2	1.5v, Type 4F
R_1	1 2-watt, ww potentiometer (ZERO ADJUST)
R_2	0.1 ww
R_3	1 ww
R_4	50 ww
R_5	10 (General Radio Type 301) (TRANSMISSION)
R_6	300 (10-turn potentiometer) (NEAR ADJUSTMENT)
R_7	50 ww
R_8	1000
R_9	500 2-watt, ww potentiometer (CALIB ADJUST)
R_{10}	2300 ww
R_{11}	60 K ww

Resistor values in ohms.
K = 1000.
ww = wirewound.

3. SERVICE TESTS

Service tests of a Calibrator were made at the National Bureau of Standards Visual Landing Aids Field Laboratory, Arcata, California, where there were four transmissometer installations which could be used for making cross-checks with the Calibrator. Three of the transmissometers had 500-foot baselines; the fourth had a 750-foot baseline.

Field installations were made in accordance with the directions given in Appendix A, Section A.1. Pads were installed in the ground at each of the four NEAR positions. Aligning pins projecting about 0.25 inch above the surface of the pads were provided in each pad to position the base plate of the telescoping stand. The operational and calibration procedures given in Appendix A, Sections A.2 and A.3, were developed and were used for the service tests.

The transmittances over the four transmissometer baselines were determined periodically and compared with the transmittances determined by the respective transmissometers. The 100 percent settings of the transmissometers were made using the method outlined in NBS Report 2588, paragraph 6-3.2.1, using a 100 percent setting based upon observations made on several days.

For a group of 45 measurements made when the transmittance was 0.90 or higher and when atmospheric conditions appeared to be uniform, the average difference between the transmittances determined by the Calibrator and the transmissometer was 0.012. On only five occasions was the difference 0.025 or larger. Nonuniformity of atmospheric conditions over the transmissometer baseline or during the period required to make measurements made the accuracy of an additional 28 measurements questionable. Under these conditions differences in transmittance as large as 0.05 were obtained. It should be noted that the test site, Arcata Airport, is noted for the nonuniformity of atmospheric conditions, and conditions there probably do not represent typical service conditions.

The largest differences were obtained with the transmissometer having a 750-foot baseline. Less uniform atmospheric conditions and lower accuracy in the 100 percent settings of the transmissometer itself are considered the most probable reasons for the poorer correlation.

In order to obtain the accuracy of measurements reported above, it was necessary to follow carefully the calibration and operation procedures outlined in Appendix A. Larger differences were obtained during preliminary measurements for which less care had been given to accuracy of alignment or to the temperature effects during calibration adjustment of the Calibrator.

The calibration and linearity of the Calibrator were stable throughout the service test period. After a careful initial check and adjustment, a recalibration check semiannually was adequate. A recalibration would, of course, be required after a change of the photocell or of R_9, R_{10}, or R_{11}. In addition, after a change of photocell, a linearity check would be required.

4. DISCUSSION

During the development of the Calibrator, consideration was given, of course, to other methods of obtaining the 100 percent setting of the transmissometer. Brief discussions of some of these methods and the reasons for rejecting them are given in Appendix C for reference.

5. SUMMARY

A portable transmissometer Calibrator has been developed. The instrument is battery operated and requires no external source of power or signal lines. With this instrument, the 100 percent setting of the transmissometer can be determined, under uniform atmospheric conditions, with an expected error of approximately 0.015. The instrument is convenient to use. However, procedures must be carefully followed and care must be given to the establishment of the field positions. The major sources of error in using the Calibrator are nonuniform atmospheric conditions over the transmissometer baseline and changes in transmittance during the period in which the calibration is being made.

APPENDIX A

OPERATING INSTRUCTIONS

A.1 Field Installation

Establish a FAR position on the receiver stand as close to the receiver lens as is convenient, taking care that there is an unobstructed view of the transmissometer projector from this position. This position should be not more than one foot from the lens. Mount the FAR position holder for the photocell at this position. See figure A-1.

Establish a NEAR position at a point on the line between the center of the projector lamp and the center of the photocell when the latter is at the FAR position, and at a distance from the projector equal to one-fifth the distance to the FAR position. Tolerances in the location of this position are ±2 inches vertically, laterally, and longitudinally. Place a pad under this location to support the telescoping mast at the proper position. Determine the height to which the mast must be extended, and scribe indexing lines on the mast so that it may be extended to the correct height for subsequent calibrations. See figure A-2.

Calibrator at NEAR Position

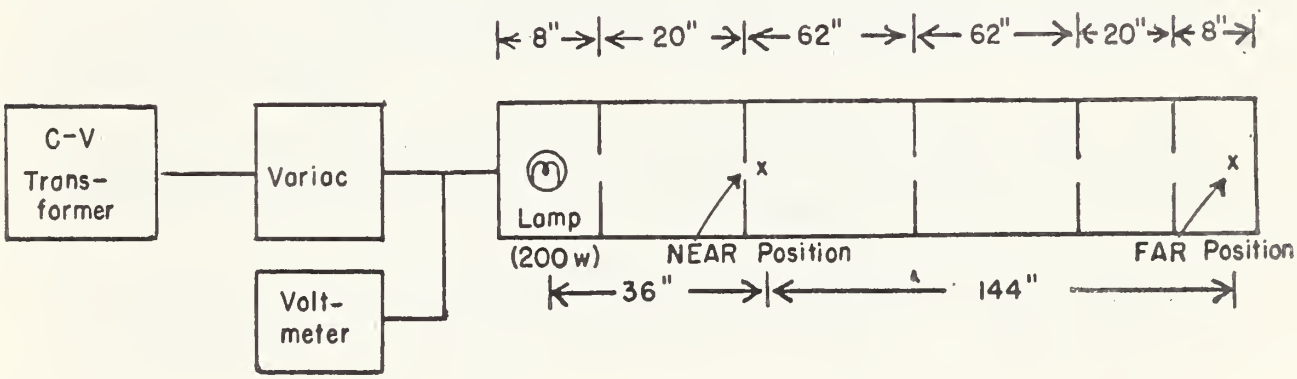
Figure A-1

Calibrator at FAR Position

Figure A-2

A.2 Calibration and Linearity Check of Calibrator

A.2.1 Calibration Equipment. An arrangement in which the photocell can be placed in a NEAR and a FAR position is required for adjustment adjustment of the Calibrator. The distance of the FAR position from the lamp must be exactly five times the distance from the lamp to the NEAR position. The system must be well baffled so that no reflected light strikes the photocell. A convenient arrangement is shown in figure A-3. The openings in the baffles should be not greater than three inches. The baffles may be made of metal or of wood. If the baffles are made of wood, metal inserts should be used at the openings. The edge of each opening must be finished to a chisel edge so that reflections off the edges will not strike the photocell. All baffles should be finished with flat black paint. If a dark room is not available, the baffles may be built into a light-tight box about 12" by 12" by 16' finished flat black on the inside. The lamp should be a 200-watt projection lamp.



Note: Forced ventilation of the lamp chamber is recommended.

Figure A-3

A.2.2 Initial Calibration of the Calibrator.

Note: In performing a calibration, the following precautions should be taken to insure stability of the equipment and accuracy of the calibration:

a. Apply power to the constant-voltage transformer at least 10 minutes prior to the calibration.

b. Turn POWER switch of the Calibrator to ON at least 5 minutes prior to the calibration.

c. Allow the photocell to adjust to room temperature after each balance. Keep the photocell in position in the calibrator box only for the time required for a balance (30 seconds, approximately). (The sensitivity of the photocell varies appreciably with temperature, and the temperatures at the two calibration positions may not be the same.)

1. Place the photocell in the FAR position. With the photocell dark (lamp off), the GALVANOMETER switch in the OFF position, and the POWER switch in the ON position, adjust the mechanical zero of the galvanometer, getting it as close to zero as possible using the light spot, not the pointer. Place the POSITION switch in the NEAR position; turn the TRANSMISSION adjustment to zero; close the GALVANOMETER switch, and use the ZERO ADJUST to adjust the electrical zero of the instrument so that the galvanometer reading does not change as the GALVANOMETER switch is opened and closed or as the POSITION switch is turned from NEAR to FAR. Use this reading as the galvanometer zero.

2a. Note: In this step and the steps following, turn the GALVANOMETER switch to ON only when a balance is being made.

Turn POSITION switch to FAR and turn the TRANSMISSION adjustment to 100. Turn the NEAR ADJUSTMENT clockwise as far as it will go. Turn on the lamp and adjust its intensity until the circuit is balanced (galvanometer reads zero). Use the NEAR ADJUSTMENT to make the final adjustment if necessary. Allow sufficient time (30 seconds) for the photocell sensitivity to stabilize, but keep time to a minimum to reduce temperature effects. Balance the circuit as closely as possible.

2b. Keeping the lamp voltage constant to within 0.1 volt, place the photocell in the NEAR position. Turn POSITION switch to NEAR. Use the CALIBRATION ADJUST to balance the circuit. Keep the time that the photocell is in NEAR position to a minimum (30 to 60 seconds) to reduce temperature effects.

Note: The Calibrator is very sensitive to changes in light intensity when in the NEAR position. A change in lamp voltage of only 0.03 volts will produce a change of about 3 millimeters in the galvanometer reading. If the galvanometer is not steady, use the average reading.

3a. With the photocell in the NEAR position, the POSITION switch on NEAR, the TRANSMISSION adjustment at 100, turn the NEAR ADJUSTMENT to the extreme counterclockwise position and adjust the lamp intensity until the circuit is balanced (using the NEAR ADJUSTMENT for a fine balance if necessary).

3b. Keeping the lamp voltage constant, place the photocell in the FAR position and use the TRANSMISSION adjustment to balance the circuit. Note this reading.

4. If the reading obtained in step 3b is off-scale (above 100), repeat steps 2a and 2b using the extreme counterclockwise position of the NEAR ADJUSTMENT and steps 3a and 3b using the extreme clockwise position.

5. Subtract the TRANSMISSION reading at the FAR position from that at the NEAR position. If this difference is less than 1.5, the linearity of the photocell is satisfactory and further linearity corrections are unnecessary.

6. If the difference obtained in step 5 is greater than 1.5, either replace the photocell or repeat steps 3 through 5 using three or four different settings of the NEAR ADJUSTMENT, and obtain a correction curve by plotting the differences obtained against the settings of the NEAR ADJUSTMENT. This curve may then be used to obtain the correction to be added to the TRANSMISSION reading obtained when calibrating a transmissometer, thereby obtaining the correct transmission to be used in setting the transmissometer.

A.2.3 Subsequent Calibrations. As the calibration adjustment of the Calibrator is not dependent on the sensitivity of the photocell, but only on its linearity characteristic, frequent calibration is not required. A semiannual calibration check should be sufficient.

Note: Calibration is required whenever the photocell is changed. If the photocell meets the linearity condition specified in step 5 above, a complete calibration check as outlined above is not required for routine calibration checks. Instead, the procedure may be abbreviated using only steps 1, 2a, and 2b with the NEAR ADJUSTMENT in about the position in which it is generally used in service. If the photocell does not meet the conditions specified in 5 above, and a correction curve is used, use steps 1 and 2 with the NEAR ADJUSTMENT in the position where the correction is zero.

A.3 Operation - Determination of the 100 Percent Setting

Note: This work must be done at night or during late twilight.

Note: It has been found that on calm nights the small amounts of dust raised in driving from the projector site to the receiver site, the smoke from a vehicle exhaust and the smoke from cigarettes will disturb the uniformity of the transmittance over the transmissometer light path and can produce significant errors for many minutes. Care must be taken to avoid these sources of error.

1. Turn the Calibrator POWER switch to ON about 15 minutes before the Calibrator is to be used. Put the photocell outside so it will come to air temperature. Leave the GALVANOMETER switch at OFF.

2. Cover the transmissometer projector with an opaque cloth or shield. (Do not turn off the projector. Wait several minutes after an hourly cutoff of the projector for the intensity to stabilize before making a balance.)

3. Place the photocell and Calibrator at the NEAR position.

4. Adjust the mechanical zero of the galvanometer, if necessary.

5. Turn the TRANSMISSION adjustment to zero, the POSITION swith to NEAR, and the GALVANOMETER switch to ON. Adjust the electrical zero with the ZERO ADJUST. Turn the GALVANOMETER switch to OFF.

6. Uncover the lamp. Turn the TRANSMISSION adjustment to 100. Turn the GALVANOMETER switch to ON and use the NEAR ADJUSTMENT to balance the circuit. Allow at least two minutes for the photocell sensitivity to stabilize. Turn the GALVANOMETER switch to OFF. Re-cover the projector.

7. Place the photocell and Calibrator in the FAR position. Adjust the mechanical zero of the galvanometer, if necessary.

8. Turn the POSITION switch to FAR, the TRANSMISSION adjustment to zero, and the GALVANOMETER switch to ON. Adjust the electrical zero. Turn the GALVANOMETER switch to OFF and the TRANSMISSION adjustment to 100.

9. Uncover the lamp. Balance the circuit by means of the TRANSMISSION adjustment. Allow at least two minutes for the photocell to stabilize.

10. Read the transmission. The result obtained is the transmission over the transmissometer path. Adjust the transmissometer to give this reading.

11. Turn the Calibrator GALVANOMETER and POWER switches to OFF.

APPENDIX B

GRADUATION DATA FOR TRANSMISSION SCALE

Note: These data are based upon a scale on which the 100 point is 260°0' from the 0.0 point.

Transmission (Percent)	Angle (Degrees)	Angle (Minutes)
100	260	0
99	257	55
98	255	50
97	253	44
96	251	38
95	249	31
94	247	26
93	245	20
92	243	14
91	241	7
90	239	0
89	236	52
88	234	43
87	232	34
86	230	25
85	228	17
84	226	9
83	224	0
82	221	51
81	219	41
80	217	31
79	215	20
78	213	9
77	210	57
76	208	45
75	206	32
70	195	25
65	184	15
60	172	52
55	161	12
50	149	19
45	137	17
40	125	2
35	112	11
30	99	10
25	85	48
20	71	46
15	56	59
10	41	14
05	23	43
00	0	0

APPENDIX C

DISCUSSION OF ALTERNATIVE CALIBRATION METHODS

1. <u>Measurement of total output of projector using an integrating collector over the projector lamp.</u>

This method was rejected for the following reasons:

a. The ratio of the intensity of the projector in the direction of the receiver lens to the total output of the lamp is not fixed. This ratio varies with focusing of the filament within the lamp. Measurement of the ratio in the laboratory would overcome this difficulty (however, see b below), but the ratio is dependent upon projector alignment. In addition, the ratio changes throughout the life of the lamp as the shape and position of the filament change and as the lamp blackens.

b. With this method, variations or changes in the sensitivity of the receiver are not taken into account. Although the sensitivity of the receiver is more stable than is the intensity of the projector, a satisfactory calibration method should take receiver sensitivity into account.

NOTE: During the remainder of the discussion of this method, the sensitivity of the receiver, except for the changes produced by the setting of the iris diaphragm, is assumed to be constant.

c. If this method is to be used in making the 100 percent setting when a new lamp is installed, a calibrated iris diaphragm must be used on the receiver so that the relative sensitivity of the receiver is known for all settings of the diaphragm. The correct setting of the diaphragm is found from the equation

$$S/S_o = K/K_o$$

where K is the Calibrator reading obtained with the new lamp,

K_o is the datum Calibrator reading,

S_o is the setting of the diaphragm which would give the correct 100 percent setting if the output of the lamp were K_o, and

S is the correct setting for the lamp being installed.

Note that this equation is applicable only when the lamp is aligned so that its peak is directed toward the receiver. In addition, if the spectral sensitivity curve of the phototube of the receiver is not very similar to that of the Calibrator, an error will be introduced except when the color temperature of the projector lamp is very nearly the same as the color temperature of the standard lamp which was used in the calibration of the Calibrator. Thus the lamp-voltage adjustment of the projector can not be used.

d. After a new lamp has been installed and the initial 100 percent setting has been made, a calibrated iris diaphragm is not needed for subsequent adjustments of the 100 percent setting. However, the reading for which the transmissometer should be set can not be obtained directly from the Calibrator but may be computed from the following relation:

$$R_1 = R_0 K_1/K_0$$

where R_1 is the reading to which the transmissometer is to be adjusted,

R_0 is the transmissometer reading before adjustment,

K_1 is the present Calibrator reading, and

K_0 is, as before, the datum Calibrator reading.

This relation is valid only if the receiver sensitivity and the projector alignment have not changed.

e. Calibration of the Calibrator can not be readily performed in the field.

2. <u>Measurement of the intensity of the projector.</u>

This method eliminates difficulty (a) listed in 1 above if the intensity measurement is made on the line of sight between the projector and the receiver at a distance of not less than 50 feet, and preferably at about 100 feet, from the projector. However, the other difficulties listed under 1 remain. In addition, a correction in the intensity measurement will be required for the transmittance of the path between the projector and the Calibrator unless the visibility is of the order of 3 miles or more.

3. <u>Measurement of the intensity of the projector and the sensitivity of the receiver.</u>

The problems encountered with this method are the same as those encountered with method 2 except that a calibrated iris diaphragm is not required. Instead, if the Receiver Calibrator is external to the receiver tube, the diaphragm may be set to the desired position by means of the Receiver Calibrator. In addition, with this method, changes in the sensitivity of the receiver are compensated for. However, the calibration equipment is more complicated since two units must be used and both must be kept calibrated. Calibration of either of these units in the field will be difficult.

4. <u>Use of an auxiliary transmissometer projector and receiver.</u>

With this method a second projector and a second receiver could be mounted beside the present projector and receiver and could be operated from the present power supplies. The 100 percent setting of these instruments would be made during clear weather using the present technique.

These instruments would then be used only for check purposes. The chief disadvantages of the method are cost (for a separate set would be required for each transmissometer) and problems of maintenance of the calibrating instruments.

The use of a second complete transmissometer located farther down the runway is considered more desirable and advantageous than duplication of instrumentation at one site since this second instrument would be useful in routine operations at the airport.

5. Use of a complete, separate, portable transmissometer.

This method is, of course, fundamentally sound. However, it requires a source of fixed intensity and alignment of the source; and a receiver of fixed sensitivity and alignment of the receiver. In addition, calibration of the source and receiver will be required unless the two-distance method of calibration described in this report is used.

6. Measurement of the apparent contrast between a black object and its sky background.

The apparent contrast between a target viewed against the sky and its background is given by

$$C = C_o t$$

where C is the apparent contrast determined from the position of view

C_o is the contrast determined a very short distance from the target, and

t is the transmittance of the air path between the target and the position of view.

Thus a target could be installed at the receiver or the projector and the apparent contrast measured from the other site, as well as close to the target, and the transmittance computed. This method is fundamentally sound but requires complex instrumentation in order to obtain the required accuracy. In general, the method is suitable for daylight use only.

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

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Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

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Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

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Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering Laboratory. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

CENTRAL RADIO PROPAGATION LABORATORY

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Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. High Latitude Ionosphere Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

Radio Physics. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Millimeter-Wave Research.

Circuit Standards. High Frequency Electrical Standards. High Frequency Calibration Services. High Frequency Impedance Standards. Microwave Calibration Services. Microwave Circuit Standards. Low Frequency Calibration Services.

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